Fast Back-projection Algorithm for Synthetic Aperture Radar Imaging System with a Lightweight Unmanned Aircraft System

By Jingong Huang

Dept. of Electrical and Computer Engineering

The Ohio State University

Advisor Lee Potter

Abstract

The back-projection algorithm coherently combines backscatter or tomography data to produce images. It has been widely used in the medical imaging field and for synthetic aperture radar imaging. With back-projection, the imaging process can be very time-consuming; therefore, in this effort we have presented a fast back-projection algorithm that provides significant computational savings with only modest loss in image quality. This paper introduces the back-projection algorithm and two fast back-projection algorithms. In addition, this paper discusses an IQ balance method necessary in practice for calibration of hardware imperfections in a quadrature receiver.

Background

Design a SAR system to operate on a lightweight UAV platform

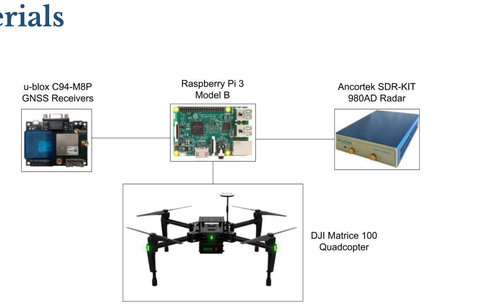
Design Goals

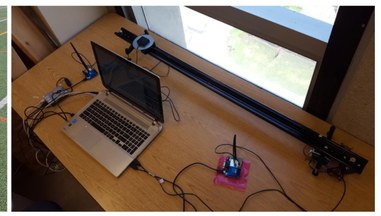
- 50 cm SAR resolution
- 1 meter georegistered accuracy
- 50 meter slant range
- 3.5 kg system mass

Design Constraints

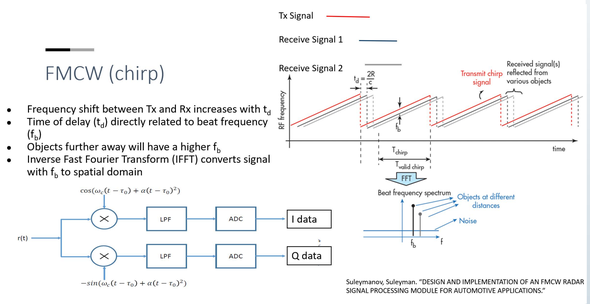
- FCC & FAA regulations limit both bandwidth and available spectrum
- UAS pilot license and institutional requirements

Materials



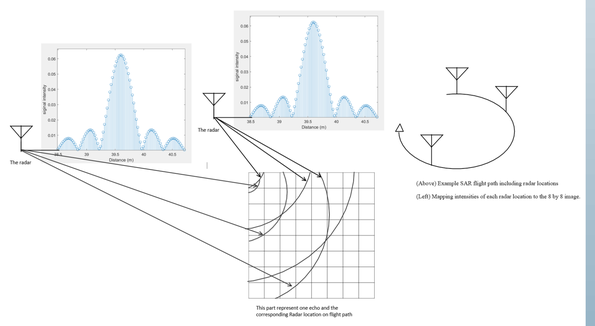


Methodology

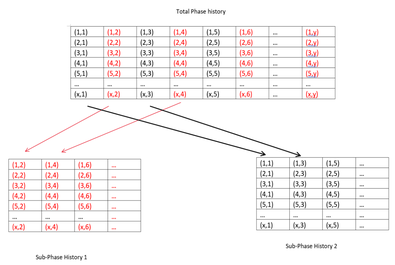


Suleymanov, Suleyman. "DESIGN AND IMPLEMENTATION OF AN FMCW RADAR SIGNAL PROCESSING MODULE FOR AUTOMOTIVE APPLICATIONS."

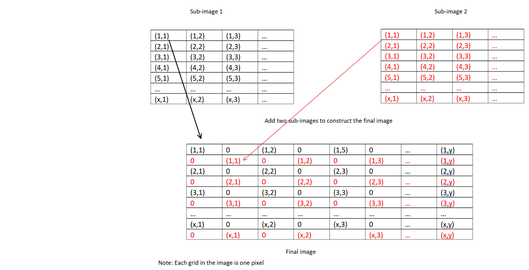
Back-projection



Fast Back-projection (Divide phase history)



Fast Back-projection (Adding sub-images)



Results

2D and 3D simulation result

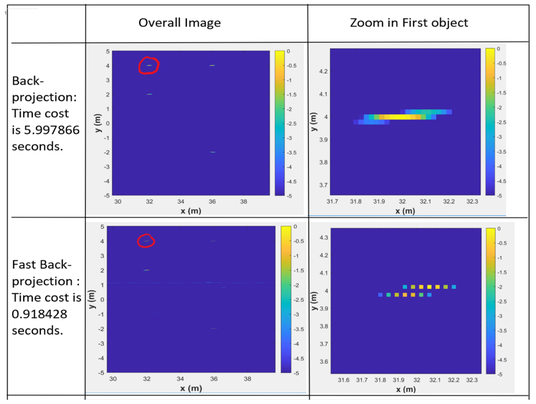
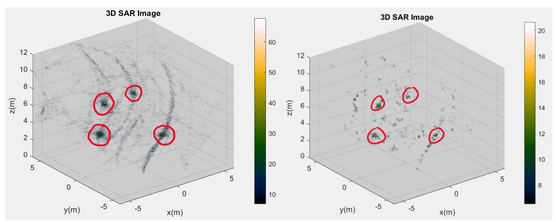


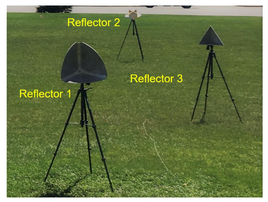
Image formation time: 121 seconds

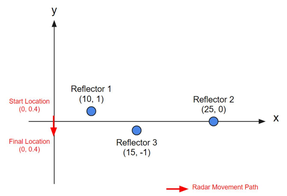
Image formation time: 19 seconds

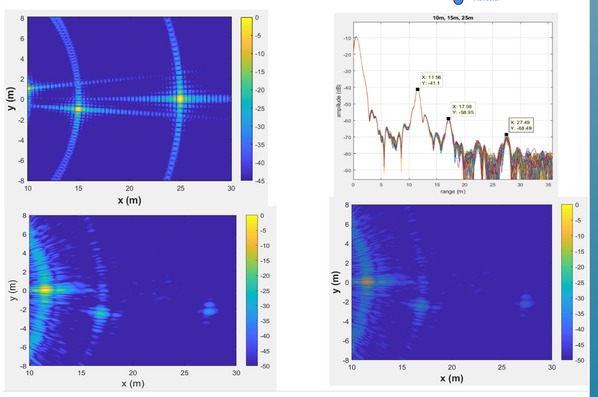


Experimental Results

- Testing was done using an Ancortek Radar system with three reflectors on a soccer field





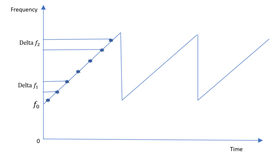


Experiment Analysis

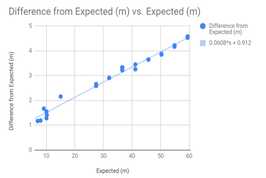
- The error may have been caused by a hardware offset, R_0, or inaccuracies in the linear chirp causing errors in the delta f parameter which affected the output of the equation below.

$$Range\ location = R_0 + n * \frac{c}{2} * \frac{1}{Delta\ f}$$

$$Range\ location = R_0 + n * \frac{c}{2} * \frac{1}{Delta\ f} + n * \frac{c}{2} * error$$



In summary, errors in R_0 and $Delta\ f$ are conjectured to arise from the physical transceiver device and are consistent with the linear fit experimentally observed in this figure. Corrections to these parameters are easily incorporated into the imaging algorithm



Recommendations

1. Verify the linear relationship between distance and error to prove the image accuracy
2. Using Interferometric SAR to improve the accuracy of 3D image
3. Using FPGA to improve computation power on drone

Acknowledgements

First, I would like to express my very great appreciation to Professor Potter for his valuable and constructive suggestions during the planning and development of this research work.

Next, I would like to thank my teammates, Brandi Downs, Sarah Greenbaum, David Giffin, Dane Miller, Aaron Pycraft, Joy Smith, Luke Smith, Daniel Wharton, Shiqi Yang, Kion, Isaac Zachmann, Venkat Garapati for their wonderful collaboration during the three semesters.